The Big Idea

- In quantum science, we often cannot see the things we want to measure because they are so small, so we have to use tools to indirectly learn about them.
- Resonance is an important tool to make indirect measurements. Resonance is when an object experiences an oscillating force or vibration that is close to one of its “natural” frequencies at which it oscillates easily.
- We can use the vibrations of sound waves to learn about the shape of an object via acoustic resonance.

Materials

<table>
<thead>
<tr>
<th>Demonstration</th>
<th>Pan Flute (per group)</th>
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<tbody>
<tr>
<td>Swings, Glass bottle with water</td>
<td>Boba straws-3</td>
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<td></td>
<td>Tape</td>
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<td></td>
<td>Scissors</td>
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<td>Cell phone with white noise generator</td>
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There are enough supplies for 20 groups per rotation.

Prep Work

Prepare before the session:

- Phone fully charged/bring phone charger and with high volume
- Make sure you have the white noise app and links as mentioned in resources section.

Procedure

During session:

- Ask the participants what they know about resonance. Collect information from their responses: emphasize key words such as vibrations, oscillations, amplifications, etc. Some examples you may hear include:
  - Singing in the shower and your voice sounds extra-amplified (sound reflected off the shower walls causes the walls to vibrate with the natural frequency of the shower space)
Instruments (does the instrument have a particular shape or opening (cavity) where a vibrating sound wave can cause another vibration in the instrument and amplify the sound?)

- Using a microwave (when food molecules absorb microwaves, they start vibrating and at a resonant frequency with the microwaves, causing it to heat up and cook)
- Pushing someone on a swing with little effort gives the swinger a boost (push is at the exact same frequency that the swing naturally moves with)

Demo #1: little swings (main concept: objects have a natural resonant frequency where they easily oscillate)

- Explain the key concept of resonance: objects have “natural” frequencies at which they oscillate easily, and resonance describes when the object experiences a forced vibration at the same frequency as the natural frequency.
- Using the visuals on the handout, also explain the terminology of frequency: the number of waves (or vibrations) that pass a fixed point over time. Can also draw some waves on the board to show high vs. low frequency.
- Little swing example: pushing with just the right force helps the swing vibrate with a natural motion. Pass out tiny swings and have one person hold it while the other gives it a push. What happens if you push it too frequently? Too slowly?

Demo #2: bottle resonance (main concept: the space/shape of an object changes its resonant frequency; also, we can hear resonance via sound vibrations)

- Sound travels through the air as vibrations of air molecules. The pitch (the tone that you hear) of a sound wave is determined by its frequency.
- When a sound is played into an enclosed space (like in your shower or the hole in a guitar), some frequencies are enhanced and get louder. These frequencies are said to be “resonant” with the object (shower space, body of the guitar).
- With the swing, we tested multiple push frequencies to find the resonant vibration. Now, we’re going to find the resonant vibration of an object.
- Blow into a bottle and demonstrate that a certain tone becomes amplified. By blowing we are sending in vibrations of air molecules, and one of those vibrations matches the natural resonance of the bottle.
- Pour some water out of the bottle and ask how they expect the pitch to change. The space inside the bottle is larger now, so how will this affect the resonance?
- Which frequencies are resonant with which space depends on the geometry of the space. So when we poured some of the water out, we changed the amount of open space inside the bottle and changed the resonant pitch.

Main activity: resonance of straws

- Take two straws of different lengths. Ask what are some ways to measure the lengths of the straws. Can they think of any indirect ways?
• Use a white noise generator on your phone to play sound through one straw and let participants hear.
• Choose a longer or shorter straw and ask how they expect the sound to change
• The resonant frequency of the straw depends on its length; so by listening to the resonant sound of the straw, we can indirectly measure its length.
• Pass out three straws to each group and have them cut into different lengths. Ask the students to try to guess which straws will make which pitches.
• Ask participant to come up with a simple rule or two to describe what they learned. This is what scientists call a model of a phenomenon.
• Now that you’ve learned about the resonance of these straws, construct a pan flute!

SAFETY / Troubleshooting / Notes
• Potential broken glass.

Resources
• Physical Phone Experiments https://phyphox.org/

• White Noise Audio file 30s
  https://drive.google.com/file/d/11hQRTZqQEJc4lq2LT08zG2UBUEhGTi-/view?usp=sharing
  https://tinyurl.com/fusewhitenoise
Background

Sound travels through air as vibrations of air molecules. The pitch (that is, the tone that you hear) of a sound wave is determined by its frequency. When sound is played into an enclosed space (a tube), some frequencies are reduced and get quieter, while others are enhanced and get louder. The frequencies which are enhanced are said to be resonant with the tube.

Which frequencies a given space is resonant with depends on the geometry of the space. In this exercise, students will discover that the resonant frequency of a tube depends only on its length.

Students will be playing white noise into the tubes. White noise is a mixture of all the frequencies of sound that we can hear. When it enters the tube, most of the frequencies are damped out, while only a few (the resonant frequencies) are reflected strongly. This results in a distinct tone corresponding to the primary resonant frequency in the tube.

Since the length of the tube directly determines which frequencies are resonant, and thus which tones will be heard when applying white noise, students will be able to sort tubes by length purely based on the reflected tone!

Optional information for your own interest, or for more advanced classes:
When sound of a given frequency is played into a tube, the sound waves travel to the back of the tube, reflect off the end, then begin travelling back. The reflected wave overlaps with the incident wave, and the two overlapping waves interfere – adding up in some places, and cancelling out in others. The way that the waves overlap, and thus how much they add up or cancel, depends on how far they travel before reflecting. For certain lengths of tubing, the waves overlap in just the right way as to completely add up, or constructively interfere. We say that a tube of this length is resonant with that frequency of sound wave.

Key Vocabulary:

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<thead>
<tr>
<th>Vocabulary Word</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Frequency</td>
<td>The rate at which a wave vibrates – for sound, the air shakes back and forth.</td>
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<tr>
<td>Resonance</td>
<td>A powerful response of a system to a specific frequency of light, sound, etc.</td>
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<tr>
<td>White Noise</td>
<td>Sound composed of all frequencies (tones) in the audible range. (20 Hz – 20 kHz). This is like white light, which contains all the colors.</td>
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<td>Interference</td>
<td>What happens when waves overlap – they can add up or cancel each other.</td>
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<tr>
<td>Constructive Interference</td>
<td>When two waves overlap so that their peaks perfectly align, and they add up without cancellation – results in a more intense wave (louder, brighter).</td>
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